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PROJECT HIGHLIGHTS

Feasibility of Reclaimed Asphalt Pavement as Aggregate in Portland Cement Concrete Pavements Phase II: Field Demonstration

<http://www.mdt.mt.gov/research/projects/mat/cement.shtml>

This research investigated the feasibility of using reclaimed asphalt pavement (RAP) to replace virgin aggregates in concrete pavements. Specifically, this research considered using minimally processed RAP (i.e., simply fractionating into fine and coarse components with no washing or crushing) in this capacity for roadways in the state of Montana. The research was conducted in multiple phases through the Civil Engineering Department and the Western Transportation Institute (WTI), at Montana State University (MSU)-Bozeman. The principle investigator was Dr. Michael Berry.



Typical RAP Pile in Montana

The first phase of research, completed November 2013, used a statistical experimental design procedure (response surface methodology – RSM) to investigate mix proportioning in concrete mixtures containing RAP to achieve desired performance criteria. Based on the RSM models, two concretes were ultimately selected for further evaluation: a high RAP mix (HR) and a high strength mix (HS). These mixes were identical sans the RAP replacement rates; the HR mix, as the name implies, had a relatively large amount of RAP with 50 percent of the fines and 100 percent of the coarse aggregates replaced with RAP. The HS mix was designed to have a higher strength by using half of the RAP (25 percent of the fines were replaced and 50 percent of the coarse). These mixes were then evaluated through a suite of tests. These mixes performed well with respect to mechanical properties and durability, and were deemed suitable for applications in the state of Montana; however, the field



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application of these concretes was not evaluated, and the mixes contained a significant portion of cement, which hindered the economic benefits of using this recycled material in concrete.

The second phase, focused on: (1) the field application of RAP concretes, and (2) further optimizing the mixes in order to reduce the amount of required cement. The field application of RAP concrete was evaluated through a field demonstration project near Lewistown, Montana, in which two RAP concrete test slabs (one HR slab and one HS slab) were placed on a roadway at the MSU/WTI Transcend Research Facility. The concretes in these slabs were batched, placed, and finished using conventional construction equipment, and no constructability issues were observed during their production. However, it is worth noting that the batching process was slightly complicated by the need to slump adjust mixes due to difficulties encountered in determining the water content of the RAP aggregates. Beyond this added requirement, this work indicates that constructability issues will not hinder the use of this concrete on larger pavement projects.



Once placed, the performance of these slabs was monitored for two years via site visits, and internal vibrating wire strain gauges. No observable damage (cracking or spalling) was observed on the test slabs during site visits over the two-year monitoring period. The internal gauges revealed that the slabs did not experience excessive shrinkage or curling, although they did reveal that the HR slab experienced slightly more shrinkage and curling than the HS mix, which contained half as much RAP.



In regards to the mixture optimization, a total of 10 mixes with varying paste contents (and subsequently cement contents) and RAP replacement rates were carried out in the lab in an attempt to reduce the amount of cement in the mixes. Based on this investigation, two mixes were chosen for further evaluation. These mixes were identical to the HR and HS mixes from the original phase of research, with the exception of the paste content and the use of water-reducing admixtures. The modified HR (mHR) mix had a coarse RAP replacement rate of 100 percent and a fine RAP replacement rate of 50 percent, while the modified HS (mHS) mix contained half as much RAP with coarse and fine replacement rates of 50 and 25 percent, respectively. Both of these modified mixes contained approximately 6.5 sacks of cement per cubic yard, which is more consistent with conventional concrete pavements, and is significantly less than the 7.5 sacks used in the original HR and HS mixes.

These mixes were then evaluated with a suite of mechanical and durability tests. The mechanical tests performed were compressive and tensile strength, elastic moduli, and shrinkage, while the durability tests were abrasion, chloride permeability, freeze-thaw resistance, and scaling. In regards to mechanical properties, the mHS mix met all MDT specification requirements for both compressive and flexural strengths, and had adequate elastic moduli. The mHR mix did not meet the compressive strength requirements, but did have adequate tensile capacity and elastic moduli. Further, neither mix exhibited excessive deformations associated with shrinkage. The amount of RAP had an obvious and significant



negative impact on the mechanical properties. As was expected, the strength and stiffness of the concretes decreased with increasing RAP, and the deformations associated with shrinkage increased with increasing RAP content.

Both the mHR and mHS mixes demonstrated adequate durability for use in concrete pavements in Montana with the exception of chloride ion resistance, and the mHS mix generally performed better than the mHR mix. For the abrasion tests, both mixes lost very little mass and had wear depths less than 1.0 mm. Both concretes were rated as “High” for likelihood of chloride ion penetration. In regards to freeze-thaw resistance, the mHR and mHS mixes had durability factors of 98 and 99 respectively, after being exposed to 300 freeze-thaw cycles. For reference, a durability factor of 80 or more has been cited as being indicative of acceptable freeze-thaw resistance. For scaling resistance, both the mixes were rated as “moderately susceptible”.

Based on the results from this study, the following conclusions can be made:

1. RAP can be processed, and RAP concrete slabs can be batched/placed/finished with conventional concrete equipment, with no major logistical issues. Further, RAP concrete slabs will not see

significant damage/shrinkage/curling throughout the first few years of use.

2. Suitable concrete mix designs containing a significant portion of RAP and conventional cement contents can be obtained by using commercially available water-reducing admixtures. The mHR and mHS mixes developed in this research contained approximately 6.5 sacks of cement per cubic yard, and had adequate mechanical properties and durability (sans chloride permeability and compressive strength for the mHR mix) to be used in concrete pavements in the state of Montana. That being said, these mixes had significantly less paste, required the use of a water-reducing admixture to achieve the desired workability, and were difficult to consolidate. Further, the process for batching these mixes involved slump adjusting the mixes with the admixture, as the nature of the RAP aggregates made it difficult to adjust mixes for variations in moisture content. All of which, may hinder their use in real-world applications.

To learn more about this project and the previous phase research, visit the [research project website](#). If you have questions, please contact Kris Christensen (krchristensen@mt.gov or 406.444.6125)

2015 Montana Summer Transportation Institute

The Western Transportation Institute (WTI) at Montana State University (MSU), in cooperation with MDT, hosted the 2015 Summer Transportation Institute (STI). STI is intended to spark interest in transportation careers, aid in the development of the next generation of engineers, scientists, planners, and designers and address the nation’s need for a diverse pool of transportation professionals. The STI recruited rising tenth, eleventh, and twelfth grade students from a mix of backgrounds and hometowns. The program was free to all selected participants with program expenses paid by a grant from the Federal Highway





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Administration (FHWA) and in kind contributions from WTI, MSU, MDT, Kittelson and Associates, and Summit Aviation. Students lived on campus while learning about career opportunities in transportation. The two-week program provided a multidisciplinary academic curriculum, which included guest speaker presentations, hands-on laboratories, and field trips.

Fourteen students participated in the program at MSU from June 14 to June 27, 2015. Students learned about all modes of transportation and gained leadership skills while working on team design-build projects. Topics and activities included road ecology, urban planning, traffic engineering, geotechnical engineering, concrete mix designs with the actual mixing of concrete batches and testing for strength, bridge design and a team design and build competition, aviation, and traffic safety/human factors. Highlights included field trips to the MDT headquarters in Helena and Gallatin Field Airport. In addition, Scott Beaird, P.E., Associate Engineer with Kittelson & Associates, Inc. in Bend, Oregon, provided an overview on the importance of traffic timing and

signalization for traffic management. Scott is working on a traffic signal timing project on Main Street for the City of Bozeman, and students learned about the various mechanisms used to detect vehicles as they approach the intersection, as well as the average times allowed for pedestrians to cross an intersection. They were then able to visit a traffic signal box to see firsthand how they are programmed and operated. Furthermore, the participants learned about college preparation and career planning. During the evenings and weekend, STI students participated in educational, sports, and team-building activities.

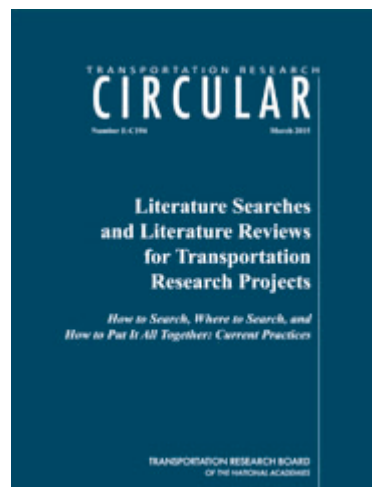
More information about this year's program can be found on Research's website at: <http://www.mdt.mt.gov/research/projects/admin/summer.shtml> or contact Kris Christensen (406.444.6125 or krchristensen@mt.gov).

STI program and application information can be found on WTI's website at <http://www.wti.montana.edu/education/summertransportationinstitute/>.

LIBRARY CORNER

Literature Searches and Literature Reviews

The Transportation Research Circular E-C194 entitled [*Literature Searches and Literature Reviews for Transportation Research Projects*](#) describes what literature searches and literature reviews are and why they are used. The Circular explains how to conduct searches and how to write effective reviews. Searching hints and recommended databases



are included. There is a series of webinars that correspond to the Circular and can be found on the [Transportation Research Board website](#).

Literature Search

A literature search is a series of searches performed in order to find relevant and related information on a topic. Comprehensive literature searches are thorough and spread across many formats and resources. The results of the search are then compiled in a list that is saved in either in a spreadsheet, document, or citation manager.



To assure that the literature search covers everything and is as thorough as time allows, the Circular lists six steps to the literature search process. They are described briefly below.

Six Steps of a Literature Search

Step 1: Define the Search Topic and Scope

Ask questions in order to gain insight of the topic. If conducting a literature search for someone, ask questions to confirm that both parties understand the information needed. Performing a brief cursory search on the topic can increase understanding and assist with narrowing the scope of the literature searches. The Circular contains questions to aid in defining the topic and scope.

Step 2: Choose the Resources to Search

Many resources are available to search including databases, catalogs, and search engines. In order to find the most relevant information, searching a combination or all of the mentioned types of resources is important. There are databases for specific categories of topics such as transportation and medicine that will assist searchers with locating relevant information. The [Transportation Research International Documentation \(TRID\) Database](#) is an essential database for transportation related publications. It provides access to both free and subscription based publications. The Circular includes a more detailed description of TRID and other resources, which are listed in Part II of the Circular.



Step 3: Choose Search Terms

Begin by choosing search terms related to your topic, then gather synonyms and related terms. Search terms can be a combination of terms or single words

depending on the topic. Once the search begins, more search terms can be found by looking at the results. Often databases and search engines will provide similar or related terms.

Step 4: Compile the Search Strategy and Run the Search

The Circular states, “defining the relationships between search terms and combining them are critical steps in the search process. This is called developing the search strategy” (2015). Searching using multiple terms combined by Boolean operators (e.g., and, not, or) and/or advanced search options can yield different results depending on the combination of terms and advanced search options used. Writing down search strategies helps the searcher keep track of previously searched terms and their combinations. The Circular also includes information on advanced search options such as truncation and Boolean operators. Understanding those terms will help searches produce better results.

Step 5: Review the Search Results

After conducting a search, it is best to go through the results to decide if the search terms were effective and if the results returned were relevant. The Circular advises the organization of search results into three categories: definitely related to your topic, possibly related to your topic, and not related to your topic (2015). If there are no useful results from a search, using a different search combination or searching within a different resource may help. The Circular gives information on when to end a literature search and how to discover resources that are not online.

Step 6: Organize the Results

Relevant search results can be saved in spreadsheets, documents or citation managers. Some databases also keep track of search results and their citations. Writing down the search strategies used and the citations will help the searcher find the information again later. If the search is ongoing, an RSS feed can be set-up so that when there is new information on the topic, the searcher is alerted.



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Many databases offer the full text of an article or publication for free or with a subscription. Also, many full text publications are available for borrowing through interlibrary loan or through a different database.

Literature Reviews

A literature review is an examination and synthesis of relevant literature on a given topic. The review combines the available information to show their connection and impact on the topic. For topics that do not have a lot of previous research associated with it, the literature review shows where the gaps are in research.

Many literature reviews available are not well written or do not completely synthesize the available research. The lack of useful literature reviews can make it difficult to know what information is out there and what information still needs to be gathered. Complete and thorough literature reviews can save researchers time and money.

If you are interested in learning more about literature searches and literature reviews, view the [recordings](#) and/or read the [Transportation Research E-Circular](#).

For additional information, please contact the MDT Library (mdtlibrary@mt.gov or 406.444.6338). This article was written by MDT's 2015 Research and Library intern, Akiema Buchanan.

DID YOU KNOW?

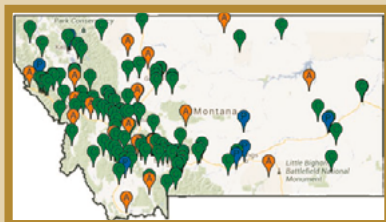
MDT Research and Experimental Projects Map

[MDT's Research and Experimental Projects Map](#)

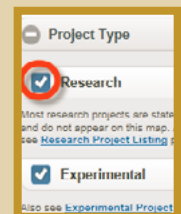
shows the location and status of projects with a location throughout the state. It offers a visual, interactive way to learn about our projects.

You can link to the map from the [Research homepage](#) by clicking on the small map image which links to the full size interactive map. You can also access the map by clicking on the Project Map link under the Experimental Projects heading and Research Projects heading in the gray sidebar of the Research homepage. One thing to note is that if you click on these links under either heading in the sidebar, initially only the projects corresponding to that project type will be shown. You can use the filter options to see all of the projects, however, once you access the map.

When you're looking at the full-size map, you can use the left-hand menu to be more specific about



the project(s) of interest; you can select project type – Research or Experimental; Project Status – Active, Pending, Completed; and District. The check marked boxes next to each option allow you to select or de-select what is shown.



If you hover over the pins on the map, you'll see the title of each project. If you click on individual pins, you'll get a pop-up box with the project name, project type, status, and district. The pop-up also contains a link to the project page, so you can see more information and related materials.



Some projects are located closely to each other, so the pins may overlap. If you zoom in on the map using the + or – sliding scale in the top left-hand side next to the filters, the individual pins will be easier to see and to click on.

For more information, contact Sue Sillick (406.444.7693 or ssillick@mt.gov).



CALENDAR OF EVENTS

January

TRB Annual Meeting -
1/10-14/16

AASHTO RAC Meeting - 1/10/16

MDT RRC Meeting - 1/29/16

February

NCHRP Synthesis Topics Due - 2/15/16

MDT RRC Meeting - 2/24/16

March

IDEA Research Topics Due - 3/1/16

TCRP Synthesis Topics Due - 3/16/16

MDT RRC Meeting - 3/29/16

NCHRP (FY2017) Projects Chosen

April

National Library Week - 4/10-16/16

MDT RRC Meeting - 4/26/16

SHRP2 Round 7

Applications Due -
4/29/16

MDT Research Topic
Statements Due -
4/30/16

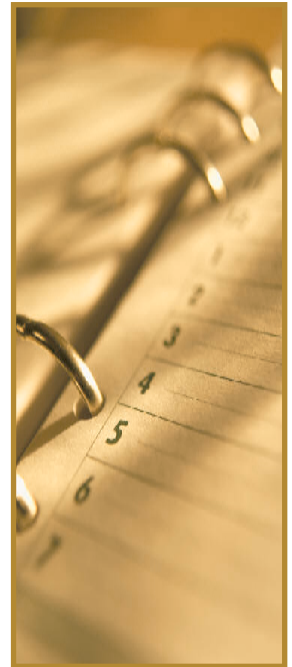
May

AASHTO Spring Meeting -
5/24-26/16

MDT RRC Meeting -
5/24/16

June

MDT RRC Meeting -
6/22/16



For additional information, please see: <http://rppm.transportation.org/Lists/Calendar/calendar.aspx>

NEW RESEARCH PROJECTS

[Montana Airport Economic Impact Update](#)

A listing of all past and current projects can be found at
http://www.mdt.mt.gov/research/projects/sub_listing.shtml.

NEW RESEARCH REPORTS

[Feasibility of Reclaimed Asphalt Pavement as Aggregate in Portland Cement Concrete - Phase 2](#)

[2015 Montana Summer Transportation Institute](#)

A listing of all past and current projects can be found at
http://www.mdt.mt.gov/research/projects/sub_listing.shtml.

NEW EXPERIMENTAL PROJECTS

[Fog Seal over Chip Seal \(FSCS\) Applications - Marias Pass](#)

A listing of all past and current projects can be found at
http://www.mdt.mt.gov/research/projects/exp_sub_listing.shtml.



NEW EXPERIMENTAL REPORTS

[Kwik Bond PPC 1121 Polyester Polymer Concrete \(PPC\) Overlay - Construction and Annual Evaluation Report 2015](#)

[Sacrificial Osterberg Cell \(O-Cell\) to Confirm Load Design - Final Report 2015](#)

A listing of all past and current projects can be found at
http://www.mdt.mt.gov/research/projects/exp_sub_listing.shtml.

REMINDER

Information on research services and products, such as research and experimental project processes and reports and technology transfer services, can be found on the Research web site at www.mdt.mt.gov/research.

MDT's library collection can be searched through the [library catalog](#). The catalog and other information resources are available through the [MDT Library web site](#).

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